

ROYAL SOCIETY.

FURTHER REPORTS TO THE MALARIA COMMITTEE, 1900.

BY

S. R. CHRISTOPHERS, M.B., AND J. W. W. STEPHENS, M.D.

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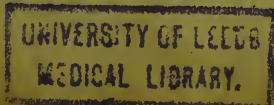
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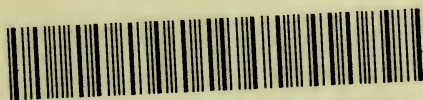
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FURTHER REPORTS TO THE MALARIA COMMITTEE OF THE ROYAL SOCIETY.

“The Native as the Prime Agent in the Malarial Infection of Europeans.” A Report to the Malaria Committee of the Royal Society. By S. R. CHRISTOPHERS, M.B., and J. W. W. STEPHENS, M.D. Received June 8, 1900.

I. *Breeding Places in their relation to Native Dwellings.*

The Formation of Breeding Places.—The breeding places of anopheles are of a somewhat special nature. Thus large bodies of water, or even large pools, rarely contain larvæ; and generally they are not found in pools which are of long standing, in which there is much vegetable matter; nor in pure spring water. Pools which are thick with suspended matter frequently contain many larvæ, and they were frequently to be found in Accra in pools brackish to the taste. One pool in which larvæ were very abundant contained as much as 0·6 per cent. of salt.

An essential condition is shelter. Anopheles larvæ are surface feeders and have a special arrangement by which they feed with the head twisted, so that the dorsal surface is brought to lie ventrally. A still surface is therefore necessary for them to thrive. The food of anopheles larvæ in the majority of specimens examined by us in Accra consisted of a unicellular organism (protococcus?). This formed the great bulk of the contents of the alimentary canal in larvæ taken from a number of pools of varying appearance. The pools in which anopheles larvæ appear to flourish best have a very faint opalescence, or even a green scum of this organism on the surface.

The occurrence of natural pools suitable to the growth of anopheles depends upon the character of the country. Thus in the hilly parts of Sierra Leone, such natural pools were very common; but in sandy districts they occur very rarely.

Wherever such pools have been found, they have, however, in nearly every case contained anopheles larvæ, quite independently of the proximity of human dwellings. In the country around Accra, however, we were unable to find a single natural breeding place.

Although a district may apparently be free from natural breeding places, yet around human dwellings breeding places are provided. In the building of native huts it is the usual practice to form the walls, or to make a platform, of dried mud. This is generally manipulated in a pit dug close at hand. After the building is completed the pit remains, and so around each native hut there are one or more of these pits. In very dry districts, such as that of Accra, with a rainfall of only 27 inches, pits of considerable size are also excavated for collecting and storing rain water, so that in and around native villages we may have as many as thirty or forty pits of varying depth and capacity. Most of these pits form breeding places of a suitable nature. Thus in Accra district, where natural breeding places are of extreme rarity, artificial ones exist in many hundreds.

The relation of Breeding Places to Ground Water and Lagoons.—As the dry season progresses the majority of the pits become dry and cease to be breeding places. The soil and subjacent rock (sand, gravel, and sandstone) are both extremely permeable to water. The drying of these pits depends, therefore, more on the general subsidence of ground water than upon actual evaporation of the water in the pit itself. The result is that breeding places exist only where the ground water is sufficiently near the surface to be reached by the deeper excavations (6 to 10 feet). In the beginning of April only those pits marked as blue spots on the accompanying map contained water. Towards the end of April a further reduction had taken place; so that in the whole district the number of pools available for anopheles did not exceed a dozen.

From the permeability of the soil and rock and the absence of rain, the ground water level was very uniform throughout the district and approximated indeed to the sea level. In wells in Accra water is reached at depths corresponding with the height of the ground above sea level. On the higher parts of the district (40 feet to 60 feet or more above sea level) in the dry season the ground water is not reached in the numerous pits existing everywhere, and in consequence large areas there are free from breeding places during the continuance of this season.

Around the borders of the lagoons, however, which are a feature of the coast, the conditions are different. Here the ground water is reached within a few feet, and even in the driest season is found in some of the numerous pits dug along the margin by the natives; and in such situations many breeding grounds accordingly occur. The number of pits is usually large in such situations, on account of the large number of villages and dwellings the sites of which have been determined by the possibility of obtaining water in the dry season.

The indirect effect of even salt lagoons and low-lying salt marshes is seen in the case of an arm of lagoon which passes in behind Accra.

The accompanying map shows that its margins are thickly populated, and abound with anopheles breeding grounds. Well on in the dry season the breeding places shown around this marsh are, with the exception of the deep wells in Accra discussed later, the only ones in the district.

Similarly, on the shores of a lagoon at Christianborg there are crowded native dwellings, and shallow pits and wells where anopheles breed plentifully.

We shall show later that anopheles easily fly considerable distances (a quarter of a mile or more), and that a considerable proportion of those from native quarters are infected. In the occurrence of native dwellings and the existence of these pits lies probably the explanation of the generally received belief that lagoons are unhealthy.

The Effect of Rain.—At the end of an exceptionally dry season pools of water had been so reduced in number as to be found only on the lagoon margin. Two heavy rainstorms then fell in close succession, and the result was a filling of pools throughout the entire district. Only a certain number of these newly-formed pools retained water for more than twenty-four to forty-eight hours, so that comparatively few permanent pools were formed. The limited extent to which permanent pools were formed (*i.e.*, those lasting four days or longer) is shown by the heavier circles on the map.

These were more numerous in the low-lying portions than on the higher lands. This is well illustrated in passing from village B (*vide* map) downwards, to the groups of houses D and E. In village B one pool only was in existence on the fifth day. After passing the 40-foot contour line, most of the deeper pits contained water. In groups D and E, 20 feet lower, not only the pits but even superficial hollows a few inches only in depth contained water. A fortnight later the majority of these pits contained anopheles larvæ.

The Nature of the Breeding Places in Accra Town.—The greater portion of Accra town is in the dry season free from surface water. There are, however, a certain number of deep wells, varying from 15 to 35 feet in depth, scattered through a considerable portion of Accra. Many of these are kept covered and constantly in use; others are not used, or only occasionally, and are not covered. A considerable number of these latter were found by us to contain anopheles larvæ in large numbers, and no doubt many more, to which we were unable to gain access, contained larvæ.

The depth of the water from the mouth of the well did not seem to influence the breeding of anopheles, as one of the deepest wells in the town (35 feet) contained larvæ.

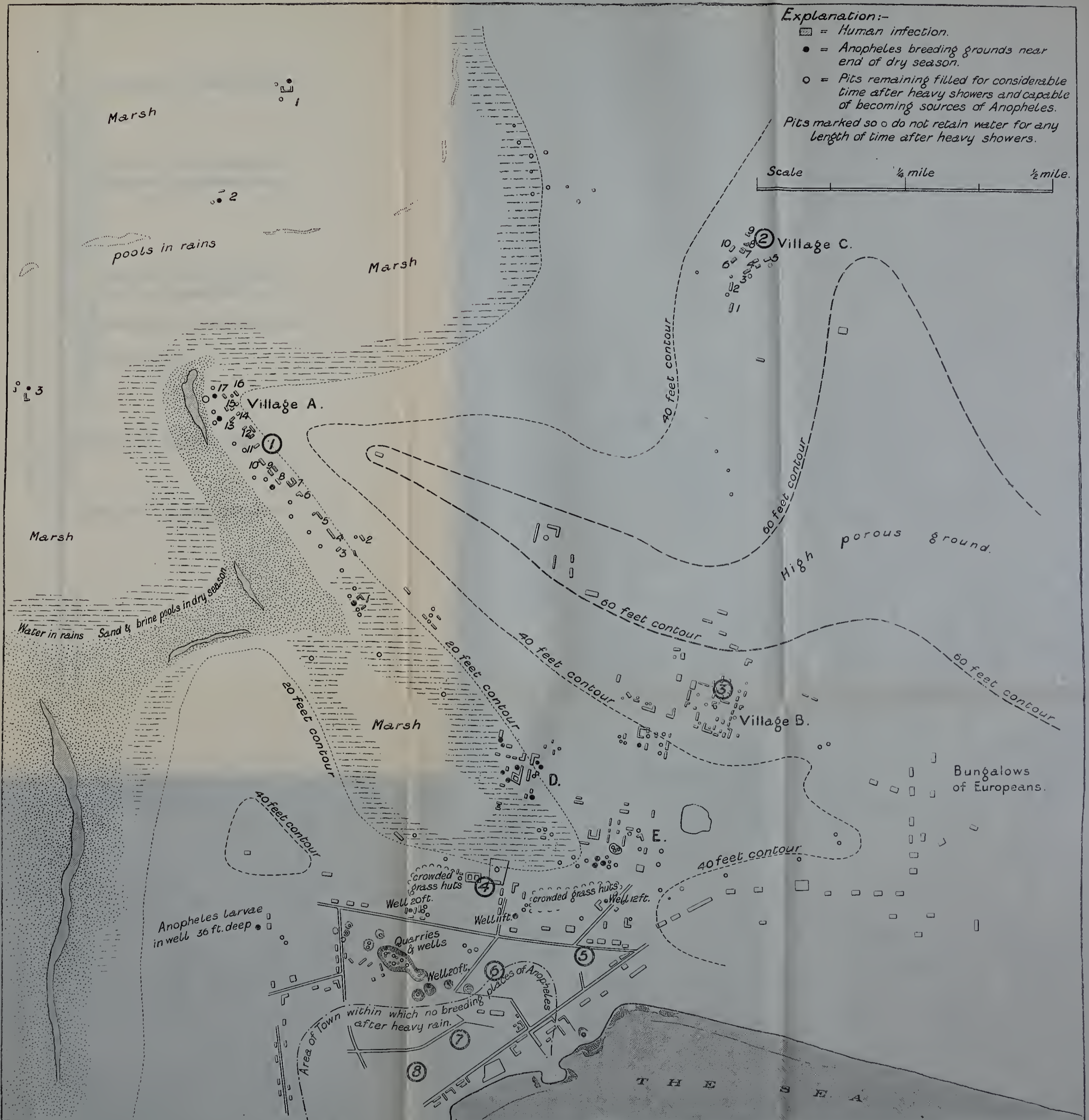
On descending these wells one frequently disturbed mosquitoes which may possibly have been using the well as a resort during the day.

Besides the wells which contained water, there were many dry wells and deep pits, which with the higher level of ground water occasioned by two heavy showers of rain contained water, and were now the breeding places of anopheles. Other pits of lesser depth were also present in numbers capable, with a still higher ground water level, of becoming sources of anopheles. There is, however, one portion of Accra where neither wells nor pits exist, which after heavy rain contained no surface pools. This portion lies in the centre of Accra (see Section).

II. *Anopheles in Native Dwellings.*

In the Presence of Local Breeding Places.—This condition we have already exemplified in Freetown, where in native dwellings, especially overcrowded ones, near the streams which teemed with larvæ, anopheles were caught in large numbers; whereas, on the contrary, in dwellings only a short distance (100—200 yards) away, they were very scanty. In Freetown we found that during the dry season the streams were the main sources of anopheles. In Accra the conditions are very different. Accra, with its scanty rainfall (27 inches) and sandy soil, may be considered the antithesis of Freetown. The native quarter of Jamestown is entirely dry, the soil is porous, and shallow pools do not exist in the town itself. We have still, however, a few deep wells in which anopheles larvæ were numerous, and on the outskirts larvæ were present even in April in a few shallow pools, which in the following week were dry. In Accra, though anopheles in the dry season of the year may be considered rare, or in some quarters possibly even absent, yet it may be noted that everywhere *Culex* (several species) occurs in myriads, derived from tubs used by the natives for storing water. In these, *Culex* larvæ were always present in astonishing quantity. A good example of a collection of native dwellings with breeding places occurs in a village close to Accra (village A, *vide* map); this village, extending along the margin of the salt lagoon, consists of some twenty huts, with numerous pigstyes and enclosures for domestic animals, all adjoining one another. The huts are of mud, mostly with grass roofs from which hang foul cobwebs and stalactites of soot. Among these, and among dirty clothing and bedding, anopheles hid themselves. It was therefore only with difficulty, even here, that under such circumstances anopheles were collected. Similar conditions were found in three isolated houses, where breeding places were in each case close at hand, and anopheles abundant.

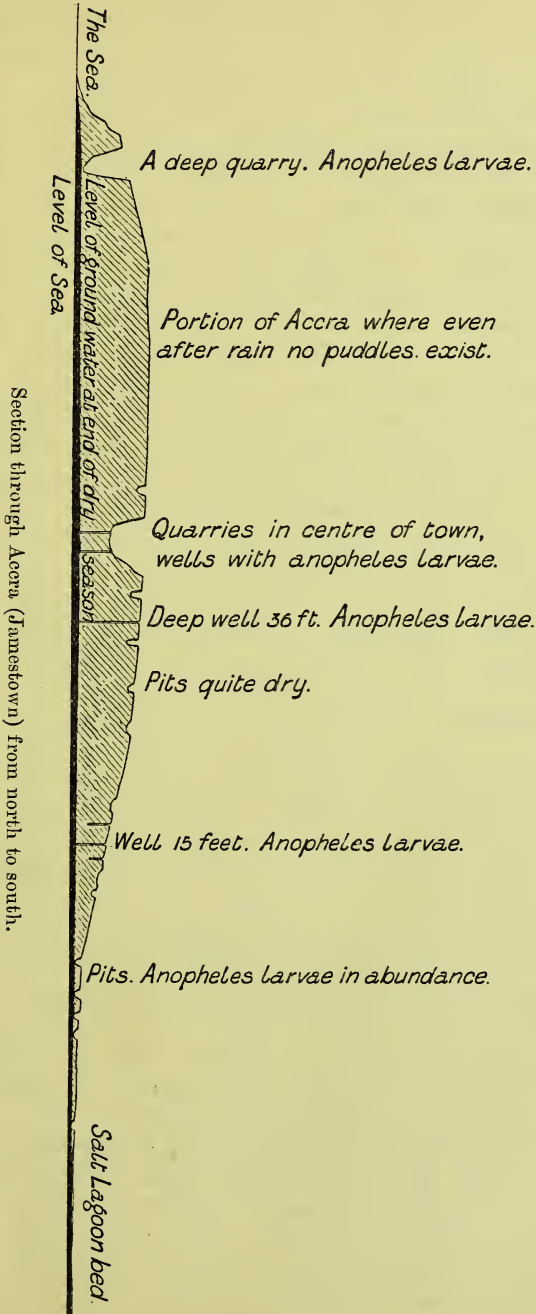
In the Absence of Breeding Places.—Where breeding places have but recently disappeared, the number of anopheles does not undergo any perceptible diminution for some weeks. Thus, in one of the isolated houses just mentioned (house 1, *vide* map), situated on the dry lagoon



SKETCH MAP of Town of Accra, Gold Coast, and Neighbourhood, to illustrate the part played by Native Dwellings in the Dissemination of Malaria.



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bed, the sole local breeding place became dry on April 14th, the nearest breeding place being then over half a mile away. Nevertheless, on April 30th, in spite of several collections having been made between whites from this house, anopheles were still numerous.

After longer periods of time, as shown both in Freetown and Accra, they eventually become rarer, and may even be apparently absent.

The detection of anopheles is not easy, when we consider the actual conditions under which the search is made. It is generally only possible to search a hut when the inmates have arisen from sleep, when the anopheles consequently have been disturbed, and when to avoid daylight they seek all the crevices and hiding places possible. If the room possesses a mud wall, they still may be found resting here gorged with blood; but where the walls and roof alike are formed of grass or palm leaves search, if delayed for any time, is frequently fruitless. Even then, however, they may still be found clinging to the thatch or rafters, or as mere formless lines on the sooty cobwebs which hang above the fireplace. The dawn of day is the most favourable time, and in European residences, where light penetrates everywhere, search later may be quite negative; indeed if anopheles are not found clinging to the outside of the mosquito net in the early morning, it may be safely concluded that they are absent. Once disturbed in this position they immediately fly off, and are not again seen until the next morning. The numbers detected by search also vary much, and a positive search may be followed by a negative, and *vice versa*. In huts where little or no light penetrates, anopheles are content to remain; they are, however, as already stated, difficult to find here. We have, however, often detected them here while in European houses, a few yards off, they were very rare after daybreak.

The impossibility then of detecting anopheles in many houses where we thought they probably existed, led us to use more delicate means of determining their presence. We have described how in Freetown by constructing artificial pools of cement, and keeping them constantly supplied with water, larvæ appeared in them after some days; so that the freedom of many houses and areas was only apparent.

In the village B (*vide* map), we have an area which had been free from breeding places for some months. Here by cement pools anopheles were detected, whereas experience had taught us that search in such a district might have been fruitless.

Our experiments in Freetown led us to the conclusion that ova did not exist alive in the earth of dried pools. These experiments repeated here have given the same result, but we found that, provided that there were moisture still in the cracks of the mud, ova taken from these would survive. At the end of the dry season, however, there can be no doubt that living ova do not exist in the site of old pools. When rain first falls, then, we should have a series

of pools ready made over an extensive area, which may be used to detect the presence of anopheles where breeding places had been for long periods absent. However, before recording the distribution of anopheles at the end of the dry season, as shown by the first rains, we should be careful that the pool used as a test is a suitable one.

We find, then, that, as a result of the first rain shower, anopheles larvæ are found near the majority of native dwellings or even isolated huts, however free they may have appeared to be from anopheles. Apart from dwellings no widespread diffusion of anopheles occurred in the Accra district, as the result of the first rains. With the object therefore of detecting anopheles, where previously they might have been supposed to have been absent, pools were examined in various native quarters.

Village A.—Here before the rains, anopheles pools were in existence. They had, however, been reduced to one or two situated at the northern extremity of the village, a quarter of a mile away from the huts of the extreme southern portion. Four days after the rains, larvæ were present again in the pools of the southern portion.

Village B.—Anopheles had previously been detected here by means of a cement pool. None of the pools in this village held water sufficiently long for us to detect larvæ.

Village C.—In this village, although there was no water nearer than a quarter of a mile, and no anopheles had been detected breeding nearer than half a mile, yet in five days after the first tornado, larvæ occurred in the village pools. Search in the huts in this village had previously detected one adult anopheles only.

The Houssa Cantonment.—A still more striking instance of this condition, of which we have now found so many examples—viz., the existence of anopheles independently of local breeding grounds—was furnished by the military cantonment at Accra. This is situated about three miles north-east of Accra, and consists of a collection of Houssa huts and officers' quarters. Before the onset of the rains no surface water existed, either locally or in the surrounding country for a mile or more around. The water supply of the garrison was derived from a deep well about half a mile away, closed in, and consisting of pure clean water. From the porous nature of the soil, small collections of water formed in the drawing of water disappeared at once. We have then in this cantonment a native quarter in the dry season for many months devoid of breeding places, and yet here again, as before stated, we found by search three anopheles, an indication that more existed.

Although after the first rain an extensive shallow sheet of water existed immediately adjacent to the huts, yet the character of the water was not then suitable, and neither culex nor anopheles larvæ were detected in it.

An Isolated Hut.—A small hut, which appeared to be used merely as a temporary shelter on a cassava farm, was found about one mile distant from any other dwellings. Anopheles larvæ occurred here about ten days after the first rain, in a pit previously quite dry. The larvæ in this isolated spot may have been laid by mosquitoes lurking in the hut, or they may have been due to anopheles occurring in the bush, independent of man, as in Sierra Leone. The pit, however, was a well, and they were not found in pools apart from houses elsewhere at this time. These pools, however, were never suitable, so that it is difficult to say how far in Accra anopheles occur, as in Sierra Leone, apart from man.

Accra Town.—It has been previously mentioned that a large portion of Accra was free from any breeding places other than certain deep wells, which nevertheless are few in number and widely separated. There are, however, pits of various depths which in the rains become breeding places of anopheles, and these are both numerous and wide-spread.

Seven days after the first rainstorm, some of these still contained water. An area was therefore chosen as remote as possible from any breeding place previously existing, and several of these pits were examined. The result was that in the majority anopheles larvæ were detected. In this portion of Accra, then, where breeding places were encountered only at considerable distances, anopheles, as shown by the pool test, were at that time widely distributed. It is in this portion of the town that most of the commercial European residences are situated.

There is, however, a portion of Accra town where a different set of conditions exists. In the very midst of the town is an area, shown on the map by a dot-and-dash line, within which neither wells nor pits exist. After an extensive fire, which burnt down this quarter, well-formed roads with cement gutters were made, and though the dwellings here are very squalid, and many culex are breeding in the domestic pots, yet even after two heavy falls of rain no surface pools existed. It will be seen in the next section that this portion of Accra offers a striking contrast, in one point, to the whole of the rest of Accra.

As a result of these observations, we come to the conclusion that anopheles exist in the neighbourhood of native dwellings in great numbers where breeding grounds are present, and that they generally exist even where for long periods, sometimes for several months, there have been no breeding grounds.

The Flight of Anopheles.—How far this widespread occurrence of anopheles is due to flight from long distances we cannot definitely say. It is certain, however, that under some circumstances anopheles may fly much greater distances than has been supposed. Thus in a

small isolated house which had been occupied by one old man, five or six anopheles were to be caught each morning. These were both male and female, the latter of which usually possessed undeveloped ovaries and imperfectly matured salivary glands, such as only freshly hatched specimens show. These anopheles could be only derived from a breeding place in a village A at the foot of the hill. This would give 300—400 yards as a flight frequently undertaken.

Also along the narrow wind-swept ridge between the salt lagoon at Christianborg and the sea, numerous wells have been excavated to a depth of 10 to 12 feet. Many of these contain numerous anopheles larvæ, which occur also in the wells farthest removed from Christianborg. These are about 600 yards distant from any dwelling.

If the anopheles breeding here are not subsisting apart from man, they must fly backwards and forwards over a distance approaching half a mile. There are many reasons, however, for regarding such a distance as unusual. Thus, in our own bungalow at Accra, we did not find anopheles, although native quarters and breeding places existed under half a mile distant.

Whether anopheles can fly such distances or not, we do not think in the majority of cases the supply of a dwelling is kept up by such means, as one knows, in the case of isolated house 1 (map), large numbers of individuals may remain over for weeks. Also it is difficult to believe that in Accra the limited number breeding in the dry season travel far to take their food.

There seems a connection also between the number present in the dry season, and the number of breeding places which have existed in that region in the rains. This is apparently shown in Accra, where the limited area from which potential breeding places are absent shows a well marked reduction in the number of children infected, whilst a similarly dry area, but with potential breeding places, showed no such reduction.

In the rains new factors are present, and a spread of anopheles undoubtedly takes place.

III. *Malarial Infection in Native Dwellings.*

The Extent of Infection among Natives.—We have seen that native dwellings may show one of several conditions:

1. They may have breeding places close at hand, and be infested with large numbers of anopheles. The example given of this was village A (map), and the isolated houses on the marsh, 1, 2, 3.

In village A we examined, as far as possible, the blood of every child under 12. Certain of the huts did not contain children, and in a few cases we were unable to obtain specimens. The houses numbered 1 to 17 are shown on the map, those in which infected children were found being indicated by diagonal lines. No house with children that

was examined was without infection, the uncoloured houses being in every case either those without children or those not examined. Table I shows the number of cases which were found by a single examination of each child's blood.

Table I.—Table to show the Extent of Infection in the Children of a Village where Local Breeding Places are present. Village A.

House.		Ring forms.	Pigmented leucocytes.	Crescents.	Total infections.	Total number examined.
1	..	..	2	1	2	2
2	..	1	1	..	2	4
3	Not examined.					
4	..	1	..	..	1	4
5	..	..	..	1	1	2
6	Not examined.					
7	..	1	3	..	4	7
8	Not examined.					
9	..	..	1	1	2	4
10	..	..	1	..	..	1
11	Not examined.					
12	..	..	..	3	3	4
13	..	2	1	1	3	3
14	No children.					
15	No children.					
16	..	2	..	1	3	4
17	..	..	1	..	1	1
1	Isolated house..	..	1	..	1	2
2	No children.					
3	Isolated house..	..	..	2	2	3
Total		18		10	25	41

This condition of general infection was also present in the isolated houses on the marsh, viz., in houses 2 and 3, the only ones containing children. It will be seen that two or more infected children may be present in each hut, while in house 7 four out of seven were infected.

Out of a total of 40 children 25 were infected. Of these 10 had crescents (gametocytes), whilst 18 had either ring forms or crowded pigment cells, indicating a present or recent attack. Seeing that one blood examination only was made of each child, it is certain that the children were suffering from an almost general infection, and were the source from which the infected anopheles, found in every house, derived their infection.

2. We next determined to what extent the infection differed from

the above in native quarters where local breeding places of anopheles were non-existent, where for considerable distances no water was available for breeding, but where nevertheless, as we have shown, a certain number of anopheles are generally present.

Village B, though containing numerous pits, was quite devoid of water in the dry season, and distant 200 yards from the nearest anopheles pool, which was situated in a group of houses at the foot of the hill. We were only able here to obtain a single blood film, but this showed numerous pigmented leucocytes.

Village C.—This was a small isolated village, situated on high sandy soil, with no water nearer than 400 yards, and no recognisable anopheles source nearer than half a mile. An examination of the children showed, however, an amount of infection not appreciably less than that shown in village A, where anopheles were breeding.

Out of ten houses examined six contained infected children. 15 children were examined in all, of these 8 showed crescents, whilst 5 gave evidence of recent infection with ring forms. (Table II.)

Table II.—Table to show the Extent of Infection in the Children of a Village where no Breeding Places are present. Village C.

House.		Ring forms.	Pigmented leucocytes.	Crescents.	Total infected children.	Total children examined.
1	..	..	1	2	2	4
2	No children.					
3	..	..	..	1	1	1
4	..	1	2	3	4	5
5	..	..	1	..	1	1
6	..	..	..	2	2	3
7	One child only	..	..	..	..	1
8	..	..	1	..	1	1
9	No children.					
10	No children.					
Total		6		8	11	16

The Military Cantonment.—In the cantonment, as we have previously shown, there exists an example of total absence of possible breeding places over a large circumferential area, and the condition has lasted at least as long as three months in the present year. Under such conditions one might reasonably have supposed that the amount of infection would be slight. On the contrary, we found here an extra-

ordinary degree of infection among the children. Out of 25 children examined at random 17 were infected, of which 6 showed crescents and 15 recent infections with ring forms. What conditions were responsible for such a high degree of infection we are unable to say. Anopheles, though probably present in greater numbers than they appeared to be, yet could not have been abundant. Three species of culex, very numerous in the huts, were examined, but yielded negative results. Inquiries showed that the men and their families had not been away from the cantonment for many months. At least it appears evident from these examples that the amount of infection in native children does not necessarily bear any very definite relation to the actual numbers of anopheles present. (*Vide* Table III.)

The Town of Accra.—In those portions of Accra where occasional breeding places occur, and where a considerable number exist during the rains, we have found an amount of infection not very different from those already mentioned. (4, 5, and 6, Table III.)

The central portion of Accra, to which we have already drawn attention as being without breeding places, even after rain, showed a very marked and striking difference. This was the first area in which the infected children were less than 50 per cent. In the position (8) this was especially marked, 5 out of 24 children only being infected; a number which is really less than it appears, as here for the most part very young children were selected.

Table III.—Table to show the Relation between Anopheles and the Amount of Infection in Native Children.

	Breeding places.	Anopheles.	Ring forms.	Pigmented leucocytes.	Crescents.	Total infections.	Total number examined.	Percentage of total infections.
Village A	Present	Considerable numbers	8	10	10	25	41	61
„ B.	Absent	Scanty	1	5	8	11	15	73
Cantonment	„	„	6	13	6	17	25	68
Accra, 4, 5, and 6 ..	Scanty	„	4	9	4	14	20	70
„ 7 and 8.	Absent	Extremely scanty or absent	0	4	7	10	32	31

The Nature of Infection in Natives.—Although among the children so large an amount of infection was present, yet in the adults parasites

were rarely found. Not only was this the case, but among the children themselves a diminution of infection occurred as the age increased. Young babies were infected in general in greatest proportion, then small children, whilst children of 10 or 12 were less commonly infected. Over 12, infected children were rare. Table IV shows this

Table IV.—Table to show Increasing Immunity with Age of Native Children.

	Babies.	Children up to 8.	Children up to 12.	Children over 12.
	Per cent.	Per cent.	Per cent.	
Village A	90	57	28	} very rarely infected.
„ B	75	50	..	
Cantonment	71	75	30	
Accra (7 and 8)	23	20	..	

diminished susceptibility as age increases, though the number of bloods examined is not sufficiently great to make these figures more than approximate. Out of 78 infections no parasite other than the malignant tertian was present, and though some infections were diagnosed from the occurrence of crowded pigmented leucocytes, yet these had the appearance of those encountered in malignant tertian cases.

In all but a few cases the infection was scanty, and apparently did not much inconvenience the child, as none of our specimens was taken from supposed cases of malaria, but from children running about and seemingly healthy.

Of the crescent cases only one or two showed them in any number. There was, however, a very rapid change of these bodies into round and flagellating bodies, and even in rapidly prepared dry films they had generally assumed this form. Intra-corpuseular developmental forms of crescents were also frequently encountered. The most curious condition of infection was that in which a few ring forms were encountered; these were frequently large forms, one-third or more the diameter of the corpuscle. In a few cases considerable "ring infections" were present, and in many others the number of pigmented leucocytes led one to think that a somewhat severe infection had lately taken place. It is unlikely that such a condition should be kept up for months without frequent reinfection, and the comparative immunity of the children in the central portions of Accra is against it.

The immunity of native races may possibly be an acquired one, from repeated infection during childhood; at any rate, there can be no lack of infection in native dwellings.

Infection of Anopheles in Native Dwellings.—Among anopheles caught in native quarters, both in Sierra Leone and Accra, we constantly find a certain proportion infected. Whether caught indiscriminately in towns or villages, or collected from individual houses, the result is the same; each batch, with rare exceptions, contains from 5 to 10 per cent. of infected specimens, a proportion which holds good at any rate for the dry season. What the proportion is during the rains we do not yet know.

In village A (map), in every house in which anopheles were caught they were infected. In the houses marked 1, 2, 3, and situated on the flat, grassy lagoon bed, we had houses exceptionally isolated, yet among anopheles caught here specimens were infected. The presence of infected anopheles in native quarters then appears to be not an occasional, but a constant, phenomenon, dependent undoubtedly upon the human infection in such places.

The Analogy between the Transmission of Malaria to Europeans and that of Ngana.—Bruce has shown that ngana is transmitted to domestic animals by means of the tsetse fly from the buffalo and wild game of a district. The trypanosoma was also found by him.

It has also been long noticed that with destruction of buffalo and wild game in a district, both the tsetse fly and ngana became less frequent.

In the very remarkable general infection of native children with an apparently mild form of malaria, and the close relation of anopheles to native dwellings shown by our investigations, and in the transmission thereby of malaria to Europeans, there is a process resembling that which takes place in ngana. Further, the analogy holds good in the conversion of the mild or innocuous type of the native disease into the virulent form in Europeans. We do, however, find severe forms also in natives. It may at least be pointed out that were a European in the Accra district (and no doubt the condition is a general one) to sleep in any native hut without a properly arranged mosquito net, he would be exposed to certain infection. Even were he to sleep a single night within a hundred yards of any native village, the risk would be very great. One of us derived his primary infection in this way six months after entering a highly malarious region. For the first time, whilst travelling, a night was spent in a native village, and, through an accident, without a net. Here, though present, anopheles were not very troublesome; nevertheless a severe infection resulted nine days later. Two other attacks were also traceable to exposure to bites from anopheles near native villages. Apart from such conditions we have never contracted malaria during a residence of fifteen months in highly malarial districts. We have also on several occasions slept, adequately protected, night after night, at the edge of swamps without any ill effect.

In most regions little frequented by Europeans, it is usual in traveling to utilise each night a hut in a native village. The attack of "fever," which is so usual after such journeys, becomes at once explicable on a knowledge of the conditions in native quarters. The gross carelessness with which mosquito nets are used—and only too frequently they are dispensed with altogether—contributes naturally to this end. (See also pp. 20—22.)

Also we have seen that towns on the West Coast of Africa differ but little in the amount of infection present from the villages, and here the European house is most frequently surrounded on every side by native hovels. In towns then, also, it is highly probable that a large number, if not the majority, of cases of malarial infection are derived, not from pre-existing cases in Europeans, but from native sources.

IV. *On the Segregation of Europeans.*

If we consider now the conditions here depicted, we see that from its peculiarities of scanty rainfall and dry soil, from the fact that in some of the areas described we have breeding places, in others not, that we have isolated huts and isolated villages with and without breeding places, and in the cantonment an isolated community under special conditions already described, we find that Accra presents us with a means of estimating the effect of various factors to which importance may be assigned in the spread of malarial infection.

We have seen that although a hut be isolated and without breeding places in the dry season, yet its inmates are infected, and infected anopheles likewise occur.

The same holds good for isolated villages, the infection presenting no appreciable difference from that of a village where there were still breeding places in the dry season.

The same condition held good for the isolated cantonment, also without breeding places in the dry season. Here, for some reason, the infection was particularly great, and the European officers were undoubtedly exposed to infection.

The same holds good for the greater part of Accra town with the exception already noted.

The conclusion from these data—and we have in Freetown partially expressed this conclusion—is that native quarters wherever existent will most certainly be sources of infection.

In a portion of Accra town, already indicated, a partial exception exists. Here probably there are no breeding places for any long period, even at the height of the rains. Although it has been shown to possess a striking diminution in infected children, yet the protection is not absolute, no doubt because it is surrounded by an infected population.

Hence the first means of obvious protection for Europeans consists in avoiding native quarters with their infected population and infected anopheles.

In Accra we have three districts of Jamestown (Accra town), Victoriaborg, and Christianborg. The first we have already described incidentally; it is composed mainly of the large native quarter, but in portions of this, or closely adjoining it, we find many of the commercial residences. A European dwelling in this quarter is thus living in the midst of dangerous sources of infection, and as it is only too common to find nets improperly used, the residents here are certain sooner or later to suffer from malaria.

In Christianborg, at the east end of Accra, the conditions do not differ materially from those in Jamestown, *i.e.*, we have here in close proximity to the European residences numerous native quarters; so that residence here constitutes exposure to serious risk of infection.

In Victoriaborg we have a different condition. This portion consists of official bungalows which occupy an isolated area, remote from both Accra town and Christianborg, and surrounded by a dry sandy area which even in the rains cannot afford many breeding grounds. It is only on the western side that the hospital and a few adjacent bungalows approach Jamestown. This condition of isolation constitutes an admirable feature, and the risk of primary infection here must necessarily be small. In the location of sites it is of the utmost importance that they should not approach the native quarters, and although bungalow 15 occupied by us was less than half a mile from the nearest large village north-west of Jamestown, yet throughout the dry season we did not detect a single anopheles.

Unfortunately no data exist to show where primary infections occur, nor do we find here any microscopical evidence of the malarial nature of febrile attacks, in some of which, indeed, we have been able by microscopical examination to exclude malaria. We must advocate again the absolute necessity for such microscopical examinations.

Further records should be kept of the houses where all attacks, especially primary ones, occur, so that evidence which is now wanting may be forthcoming as to what districts and houses are chiefly malarial.

It is, however, recognised by European residents that Jamestown and Christianborg are "unhealthy," whereas Victoriaborg is "healthy;" *i.e.*, the amount of malarial fever in the former is great, in the latter small.

Wherever such a condition of isolation has been secured, it is imperative also that all local breeding places be done away with; for if a case of malaria be imported into this district the fact that sources of anopheles are present renders a certain amount of infection from this case again possible. In Victoriaborg the very few breeding places

occurring among the bungalows, in the rains only, could very readily be abolished. In other places, less favourably situated, a complete absence of anopheles may be more difficult to secure, but those occurring are far less likely to be infected, and their destruction can scarcely ever be the herculean task presented by a large native town with many thousand inhabitants.

If with this condition of isolation at Victoriaborg we contrast the conditions in Freetown, we find that they could hardly be worse. European and native quarters exist side by side, and not infrequently a European may occupy the upper floor of a building of which natives occupy the dark cellars, which are a noxious feature of the dwellings totally unsuitable for Europeans there. The conditions of these houses are quite unsuited to tropical life; they are ill-constructed, surrounded by cess-pits, and have no verandahs. They are, in fact, most ill-adapted for life in a climate which is even more enervating than that of Accra.

In dealing with the question of anopheles in Freetown, we had to consider the conditions as we found them, and, as the most practical means for destroying the numerous breeding grounds of anopheles, we advised drainage. We should, however, lay more stress on the prime necessity for isolation, and, as it is under consideration to erect European dwellings in the adjoining hilly country, we consider that this is the only efficient way of dealing with the extremely dangerous conditions of existence there. We, however, would repeat again that, if this removal be carried into effect, strict attention must be paid to the proximity of native dwellings. It is not the elevated site in itself which will protect the Europeans there, for anopheles, as we have seen, exist in the hill districts of Freetown; it is the removal from the neighbourhood of the infected native. Consequently it is of prime importance that a native village be not allowed to spring up in connection with the European quarter, and the native quarters for servants should be removed as far as possible.

In Freetown isolation cannot fail to be most beneficial, and in the building of new houses, here and elsewhere, sites should be chosen which are as remote as possible from native quarters wherein the danger lies.

S. R. CHRISTOPHERS, M.B.

J. W. W. STEPHENS, M.D. Cantab.

Accra, Gold Coast,
May 17, 1900.

“Note on Certain Bodies found in the Glands of Two Species of *Culex*.” Received June 8, 1900.

The first (fig. 2) were found in a *culex* commonly found in the bush in Sierra Leone. This *culex* was not found in Freetown itself. The bodies occurred in about 10 per cent. of this *culex* examined.

We have referred to these bodies, which have the characters of sporozoites, in our report on the distribution of anopheles in Sierra Leone. We have not so far succeeded in demonstrating a central stained spot (chromatin) as in sporozoites of *H. præcox*.

The second were found in from 5 per cent. to 10 per cent. of a species resembling *Culex pipiens*, caught in a native village, together with anopheles and other *culex* species. So far we have found them in only one species of *culex*. In general, they are few in number, but in some portions of the gland they may be numerous. As many as half a dozen may occur in each globule of secretion. They may also occasionally be seen free in the salt solution. Their chief peculiarity is their straightness. Their nature remains so far undetermined.

J. W. W. STEPHENS, M.D. Cantab.
S. R. CHRISTOPHERS, M.B.

May 17, 1900.

“The Malaria of Expeditionary Forces and the Means of its Prevention.” Received June 8, 1900.

In our report on “The Native as the Prime Agent in the Malarial Infection of Europeans” we have shown—

1. That in all native villages examined by us, from 50 to 90 per cent. of the children were infected with malaria. That a considerable portion of these infected children contained crescentic bodies, which very rapidly took on the spherical and flagellating form requisite for the transmission of human malaria to the mosquito.

2. That in all native villages examined by us anopheles were present. Nor were they absent when breeding places had not been in existence for varying periods up to three months. That, moreover, a certain proportion of these were always infected with the mosquito phase of the parasite. Not only the village as a whole, but each individual hut, in all but rare cases, contained both infected children and infected anopheles.

These conditions have been encountered by us in British Central

BODIES IN GLANDS OF CULEX.

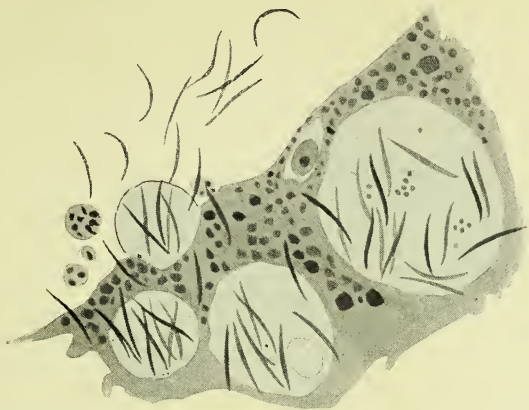


FIG. 1.—*Anopheles costalis*. Sporozoites of *H. præcox*. Fresh prep.

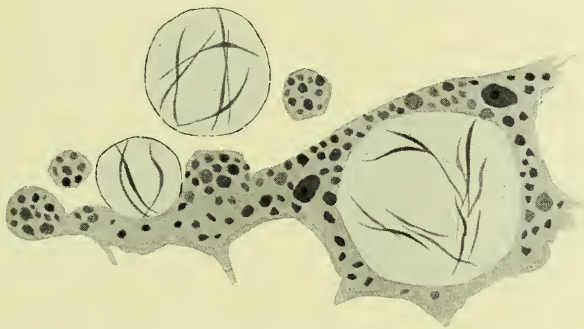


FIG. 2.—*Culex* (?). Sporozoites, nature unknown. Fresh prep.

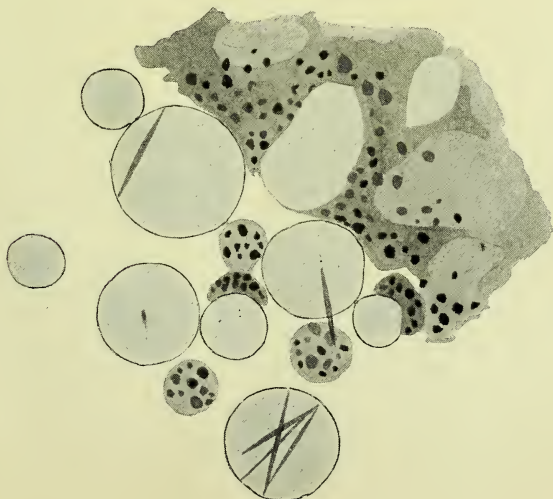


FIG. 3.—*Culex pipiens* (?). Bodies in secretion. Fresh prep.



Africa, Sierra Leone, and the Gold Coast, and there can be little doubt that they prevail universally throughout tropical Africa. These facts then are sufficient to explain why exploratory and military expeditions are attended with such a large amount of sickness and so terrible a mortality.

Very rarely does a traveller or expeditionary force pass for long distances through uninhabited districts ; while even in the most remote, such as for example the Congo forests, villages exist. In a village not only are there food and other conveniences for native porters and even for Europeans, but they are also the only places where it is possible to find a ready-made clearing for a camp. Consequently it is the invariable practice for travellers and expeditions of all kinds to pitch their camps in the village clearing—if not to sleep in the village huts. For the single traveller there is usually no other alternative than to sleep, night after night at the end of each day's journey, in some native hut. Whether a hut is occupied, or whether a camp be pitched close beside the village, matters little ; in either case infected anopheles, in greater or less number, are present.

So insidious, as a rule, are the attacks of anopheles, if few in number, that they attract very little attention.

Of the fever contracted in travelling we have in these conditions quite sufficient explanation. When night after night, for weeks or months, men, through sleeping in villages, are exposed to the bites of infected anopheles, it is quite evident that here we have the source of their sickness, and that it is unnecessary to call in the hypothetical influence of uninhabited swamps which they may have traversed. Assertions made by travellers that they have, for many days running, camped by the side of uninhabited swamps, must be received with extreme caution. Such a method of camping is in tropical Africa, to say the least, both unusual and extraordinary.

Infection, then, can most certainly be escaped by a strict avoidance on the part of Europeans of native villages and huts. If native villages are of necessity selected as sleeping places, then, whilst in such places, the most scrupulous care should be observed in the use of mosquito nets, which should be under the vigilant supervision of the medical officer of the expedition. It is essential that they should be absolutely free from holes, and, further, that they should have a protective valance at the level of the body to prevent bites being effected through the net. A further modification of the net in general use is needed to suit the conditions where the traveller uses an ordinary camp bed or, as often happens, sleeps on the ground.

The danger of being bitten and infected in villages is so great that even the use of nets would probably not ensure complete protection. It is essential, therefore, that every endeavour should be made to camp elsewhere than in a native village. Villages are a certain source

of infection, and their avoidance will certainly result in a much diminished amount of malaria in expeditions.

J. W. W. STEPHENS, M.D. Cantab.
S. R. CHRISTOPHERS, M.B. Vict.

Note.—In a later letter from Mr. Christophers, dated “Accra, 26 May, 1900,” further stress is laid on the fact that camping and sleeping in places *remote from human habitations* is in the highest degree exceptional in the case of European travellers and expeditionary forces. This fact, the writer thinks, is perhaps not sufficiently appreciated by persons not conversant with the conditions of African travel.

ERRATA.

In Report published July 6, 1900.

Page 62, line 18, *for* "titræ" *read* tibiæ.

„ 72, upper footnote, *for* 'Lancet' *read* 'British Medical Journal.'





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